

## Assessing Land Use Land Cover Changes in Langkawi Island: Towards Sustainable Urban Living

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### Abstract

*Simulating future urban growth might be useful in predicting the future urban fabric and its impact on the society, space and environment. This approach, however, needs to be undertaken with care such that it requires fundamental understanding of past and present situation. At present, urban area in developing nation is experiencing rapid urbanization and undergoing physical transformation, since majority of its population lives in urban area. It is therefore, essential that urban planners and managers understand the past and present land use land cover changes in order to predict its impacts on the society, economy and environment of the cities. This study aims to explore and assess land use land cover changes in Langkawi Island, Malaysia which has experienced significant increase of population during the last decade mainly due to the growth in tourism sector. The study monitored land use land cover changes since 1974 in order to assess the development of tourism activities and its impact on physical transformation of the island. Urban built-up area was controlled and directed towards existing built-up zone. However, annual urban expansion intensity index revealed that high speed of land use land cover transformation also occurred sporadically throughout the island especially after 1992 which might cause negative impact to the community.*

**Keywords:** GIS, Langkawi Island, annual urban intensity index, sustainable development

### Abstrak

Simulasi masa depan perkembangan bandar mungkin berguna dalam meramalkan bentuk fabrik bandar masa depan dan kesannya terhadap masyarakat, ruang dan persekitaran. Pendekatan ini, perlu diambilkira dengan berhati-hati kerana menuntut pemahaman asas situasi masa lampau dan kini. Pada masa sekarang, kawasan bandar di Negara sedang membangun mengalami perbandaran pesat dan transformasi fizikal semenjak majoriti penduduknya tinggal di bandar. Oleh itu, adalah merupakan satu keperluan perancang dan pengurus bandar memahami guna tanah dan litupan tanah masa lampau dan masa sekarang ini dalam usaha untuk meramal kesannya terhadap masyarakat, ekonomi dan persekitaran bandar. Kajian ini bertujuan untuk meneroka dan menilai perubahan guna tanah dan litupan tanah di Pulau Langkawi, Malaysia yang mengalami peningkatan penduduk yang signifikan dalam dekad yang lepas terutamanya disebabkan oleh pertumbuhan sektor pelancongan. Kajian ini juga memantau perubahan guna tanah dan litupan tanah semenjak 1974 dalam usaha menilai pembangunan aktiviti pelancongan dan kesannya terhadap transformasi fizikal pulau tersebut. Kawasan tepubina bandar dikawal dan dihalakan kepada zon tepubina sedia ada. Walau bagaimanapun, indeks kegiatan perluasan bandar tahunan mendedahkan bahawa transformasi guna tanah dan litupan tanah yang tinggi berlaku dari masa ke semasa di keseluruhan pulau tersebut terutamanya selepas tahun 1992 yang mungkin akan menyebabkan kesan negatif terhadap komuniti.

**Keywords:** GIS, Pulau Langkawi, indeks intensiti bandar tahunan, pembangunan lestari



## INTRODUCTION

Urban population will increase from 3.3 billion in 2007 to 6.4 billion in 2050 (United Nation Population Division - UNPD, 2008). Moreover, more than half of the world population is living in urban areas, yet urban land only occupies approximately 2% or 3% of the Earth's land surface (Poelmans and van Rompaey, 2010). Significant increase of urban population leads to the loss of land especially at the urban and peri-urban area which has resulted in various impacts on the environmental and socioeconomics of the community (Lambin, 2005). This phenomenon leads to the expansion of built-up area which encroaches into agriculture area. Moreover, urban and peri-urban areas experienced land use/land cover changes from agriculture or forest to housing or other economic activities away from agricultural (Simon et al., 2004; McGee, 2009a.). This requires urgent attention in order to ensure such changes can be controlled and does not jeopardize the sustainability of urban living.

Many studies had been undertaken to evaluate physical transformation of land use land cover changes at the urban and peri-urban region (López et al., 2001; Xiao et al., 2006; Koomen and Stillwell, 2007) and describe the impact of this transformation from socio-economic point of view (Suriati Ghazali, 1999; Simon et al., 2004). These studies, however, have not integrated physical information on spatial development pattern of areas experiencing shifting process and pattern of land use/land cover changes to urban land use and policy changes. Furthermore, this action can help to improve our knowledge and create a better tool to manage and plan to ensure sustainable urban development. Therefore, effective strategies for the planning of sustainable land use system at the urban and peri-urban region can be formulated (Klosterman, 2001; Sui and Zeng, 2001; Xiao et al., 2006; Wyatt, 2009).

Monitoring the dynamics of land use/land cover changes, therefore, has become an important issue in order to ensure such transformation does not jeopardize the sustainability of urban living. It is because land use/land cover changes has critical and direct impacts on the environmental conditions such as climate change and loss of the natural resources as well as human community especially in the urban and peri-urban area (Simon et al., 2004; McGee, 2009). Detecting and analyzing land use/land cover changes is an essential process in understanding various socioeconomic and environmental problems, which threaten the future of the earth surface and humanity. Various steps need to be undertaken to evaluate and improve our knowledge about current and future conditions of our environments through an understanding and predicting the drivers, process,

and consequences of land use/land cover changes at global, regional, and local scales in order to protect our environments (Pontius et al., 2001; Verburg and Veldkamp, 2005).

Land use/land cover change at the urban and peri-urban area is a complex and dynamic process that involves both natural and human systems (Xiao et al., 2006; Koomen and Stillwell, 2007). In order to monitor and evaluate dynamic land use/land cover changes, GIS and remote sensing can effectively be used (Harris and Batty, 2001; HU Zhao-ling et al., 2007). Remote sensing has the capability to acquire data timely at regular interval and becomes useful data source for land use monitoring (Yeh and Li, 1997). In addition, GIS that has the capabilities to manipulate and analyze spatial and temporal data can be used to map, monitor and identify driving forces and measure the intensity of land use/land cover transformation (Sui and Zeng, 2001; HU Zhao-ling et al., 2007). Both will provide the understanding on the dynamic process of urban land use/land cover transformation and plan towards sustainable urban living (Klosterman, 2001; Wyatt, 2009).

## Geographic Information Systems and Land Use Land Cover Change Analysis

In urban studies, GIS technology has been used in mapping the distribution of land use activities, monitoring land use land cover changes, conducting strategic planning which involve solving site selection problem and land use allocation (Stillwell et al., 1999; Wyatt, 2009). In selecting suitable site for new development, GIS had been integrated with multicriteria evaluation approach (MCE) in order to determine potential sites based on various criteria including physical, economic and environmental factors and their relative importance (Geertman and Toppen, 1990; Malczewski, 1999). Such approach allows the decision making process to be undertaken by including various considerations and expert opinion in planning for new development including access to public transportation and protection of natural areas. Another study conducted by Yeh and Li (1997) monitored and evaluated land use changes in Pearl River Delta of China using integrated GIS and remote sensing techniques. Data derived from Landsat TM images were inputted into GIS and analyzed in order to monitor temporal and spatial changes of land use/land cover changes in rapidly developing region of Pearl River Delta of China. In addition to evaluating changes and selecting suitable site for new development, GIS is also used in predicting future urban development (Stillwell et al., 1999; Koomen and Stillwell, 2007). Such analysis is useful for planners and urban managers in planning for sustainable use of space (Yeh and Li, 2001; White and

Engelen, 2000; Wyatt, 2009). The studies mentioned above were undertaken in a few regions of China and other western developed nations where GIS was used to evaluate the dynamic of urban growth in those regions. The study that used GIS to evaluate land use land cover change in the Southeast Asian region has been quite limited (Samat, 2002). Therefore, there is a need to evaluate land use changes in the context of developing nations like Malaysia since urban growth does not occur uniformly across space and time. Rapid development is usually due to top-down policy approach where the policy makers play essential role in promoting growth in certain areas by allocating industrial area or education center to act as catalyst for urban development (Goh Ban Lee, 1991; Gomez and Jomo, 1997). This study, therefore, intended to evaluate and assess land use/land cover changes in Langkawi Island, which is planned and promoted to be one of the most important tourism centers in Malaysia. The approach is hoped to give better indication on the sustainability of urban and peri-urban development in Langkawi Island.

## METHOD

This study assessed land use/land cover changes from 1974 to 2005 in order to measure statistics, location, and types of land use/land cover that had undergone significant transformation in the last thirty years. Furthermore, the study also calculated annual urban expansion intensity index in order to evaluate the speed of urban expansion at specific spatial unit in Langkawi Island. Land use land cover change can be measured using equation (1) below.

Annual expansion intensity index can be divided into five grades, which is shown in Table 1 below. In order to calculate annual expansion intensity index, a grid of 1000m x 1000m was defined as spatial unit of analysis. This grid was created using fishnet command in Arc/Info Workstation and all other analysis and display were undertaken using ArcGIS 9.2. The following section discusses the study area and data used in this study.

$$\Delta LU_{i,j,r}^{t \rightarrow t+1} = LU_{i,j,r}^{t+1} - LU_{i,j,r}^t \quad (1)$$

where,

$\Delta LU_{i,j,r}^{t \rightarrow t+1}$  = changes of land use type  $r$  at location  $i$  and  $j$  from  $t$  to  $t + 1$ ,

$LU_{i,j,r}^{t+1}$  = land use type  $r$  at location  $i$  and  $j$  at time  $t + 1$ , and

$LU_{i,j,r}^t$  = land use type  $r$  at location  $i$  and  $j$  at time  $t$ .

$$B_{i,t+n} = \left[ \frac{(U_{i,t+n} - U_{i,t})}{T} \times 100 \right] \dots \dots \dots (2)$$

where,

$B_{i,t+n}$  = the annual expansion intensity index of spatial unit  $i$ ,

$U_{i,t+n}$  = urban area in the spatial unit  $i$  at time  $t + n$ ,

$U_{i,t}$  = urban area in the spatial unit  $i$  at time  $t$ , and

$T$  = the land area of spatial unit  $i$ .

Table 1: Annual expansion intensity index and its grade.

Value	Grades
$B_{i,t+n} > 1.92$	High-speed expansion
$1.05 > B_{i,t+n} > 1.92$	Fast-speed expansion
$0.59 > B_{i,t+n} > 1.05$	Medium-speed expansion
$1.05 > B_{i,t+n} > 0.28$	Slow-speed expansion
$B_{i,t+n} < 0.28$	Slow expansion

Source: HU Zhao-ling et al. (2007).

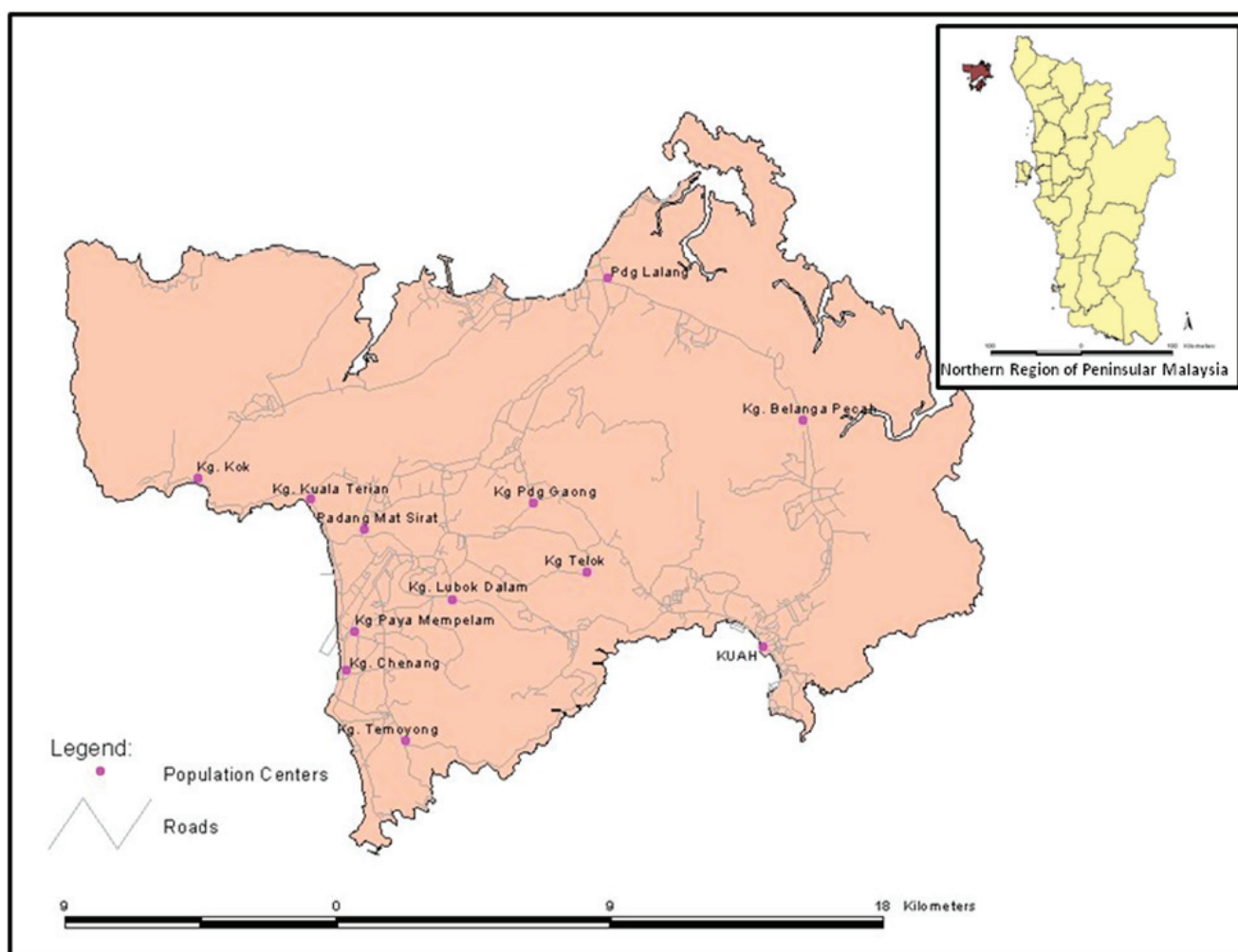


Figure 1: The study area – Langkawi Island.

### STUDY AREA AND DATA

Langkawi Island is one of the most attractive tourist destinations in Malaysia. It is a tropical island located off the north-west coast of Peninsular Malaysia between  $6^{\circ} 10'N$  and  $6^{\circ} 30'N$  latitude and  $99^{\circ} 35'E$  and  $100^{\circ} 0'E$  longitude. The biggest and most developed island is Langkawi measuring about 47,848 ha (Figure 1). Most islands are uninhabited or sparsely populated. Topography of this island is mountainous covered by forest reserved area of 26,266 ha that is 54.6% of total land area.

Langkawi has become an important tourists' location since it was given the status of a duty-free island in 1987. Originally, this island is famous for its scenic beauty, natural heritage and legends (Langkawi Municipal Council, 2005). Various tourism products namely underwater world, bird park, crocodile farm, and exhibition centre were developed throughout the island to promote tourism activity (see figure 2). In addition, hotels and other infrastructures

were developed or upgraded in order to satisfy the growing demand from tourism sectors. Tourist arrival has increased dramatically in the last five years where approximately 1.9 million to 2.3 million tourists visited Langkawi Island between 2004 and 2008. Recently, the island is given the status as a GeoPark for geological significance of rocks formation and scenic beauty (Langkawi Municipal Council, 2005). Therefore, ecotourism, that is tourism industry geared towards providing nature-based holiday experiences, has become a new attraction in Langkawi and hoped to generate economic and socio-economic benefits for the locals (Clifton, 2004). The island, therefore, is suitable to be used as a study area in order to evaluate the impact of tourism activities on land use and land cover changes in the past thirty years. Population in Langkawi island also has increased quite significantly in the last 30 years. In 1970, its population was only 23,788 people and it increased to 28,340 people in 1980. The island was declared as a duty-free-zone in 1987, experienced significant increase of its population in 1991 and 2000 where



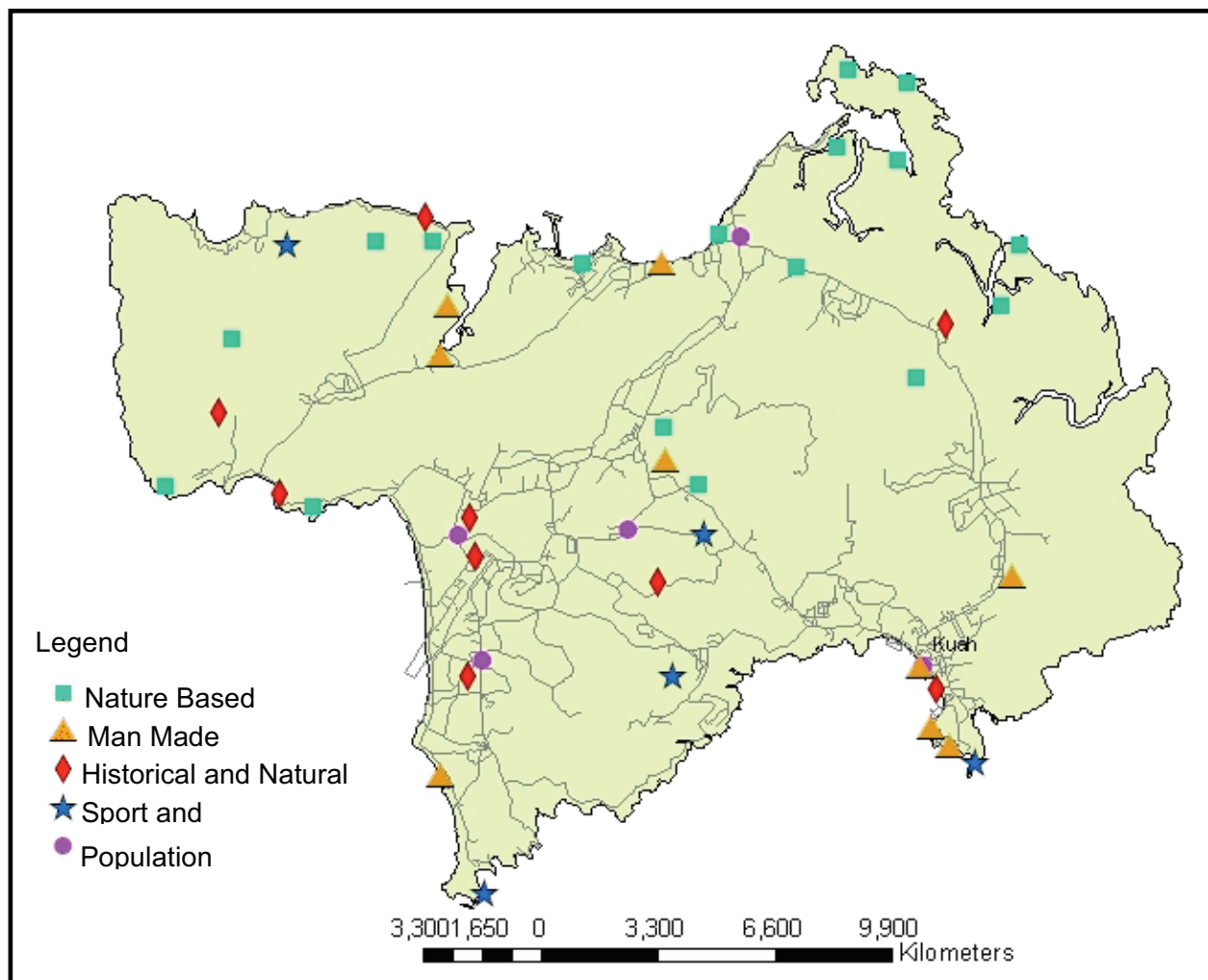


Figure 2: The study area

the island population reached 42,938 and 69,681 respectively (Department of Statistics, 2000). In 2005, Langkawi population was 84,054 and estimated to reach 98,763 and 119,009 in 2010 and 2015 respectively (Langkawi Municipal Council, 2005). The increase of its population will result in the transformation of land from other uses to urban built-up in order to cater for growing demand in housing and service sectors (HU Zhao-ling et al., 2007).

The third reason for choosing Langkawi Island as the study area is because the island has undergone significant transformation since the 1970s. The island was once deserted because of its location is quite far from the mainland. However, it is very rich in culture heritage and natural beauties. These factors contributed towards its well-know destination for tourism industry. As the island was given a duty-free-

Table 2: Major land use land cover categories and its description used for the study.

Land use/cover classes	Description
Mixed agriculture	Oil palm, coconut and mix agricultural activities
Forest	Forest, Shrubs, mangroves
Water body	Reservoir, beach and shores, streams and rivers, lakes
Build-up area	Residential, urban built-up, others
Paddy	Paddy field
Rubber	Rubber
Village	Unplanned residential area

zone status, it became significant boost for tourism industry. In order to support huge number of tourists' arrival yearly, various new development projects such as hotels, public amenities and infrastructures were undertaken. Langkawi Development Authority (LADA) was established in 1990 as a planner, catalyst and coordinator of the overall development of Langkawi. This agency was established to transform Langkawi into a major international tourist destination and to ensure that the locals derive maximum benefits from all the development programs being planned and implemented. These activities that focused on economic and urban development eroded the quality of the environment and affect the quality of life of the locals (Bahaire dan Elliot-White, 1999). It is timely, therefore, to assess the impact of such development on local environment. This includes evaluating land use/land cover changes and measure annual urban expansion intensity index from 1970s to present. It will provide significant indicators to assess the sustainability of tourism development in the island.

The study monitored land use changes in Langkawi Island from 1974 to 2005 in order to evaluate the impact of tourism development on this duty-free-island. It started with database development, which is very important to ensure the data are available, consistent, updated and free from error (Harris and Batty, 2001; Verburg and Veldkamp, 2005). Time series data were gathered from various sources such as maps, tables, field survey and reports. Land use of 1974, 1985 and 2005 were obtained from Department of Town and Country Planning, Langkawi Development Authority, Langkawi Municipal Council, and Department of Agriculture, Malaysia. Land use of 1992 was derived from Landsat TM image. Land use land cover was divided into seven categories as shown in Table 2 below. This classification was used in order to ensure uniform category of all land use land cover maps.

## RESULT AND DISCUSSION

Human activities such as agriculture, tourism, transport infrastructure and urban development

have significant influence on land use/land cover (Carsjen and van Lier, 2002). In Langkawi Island, tourism sector attracts more than 2 millions tourists from local or abroad yearly. Tourism activities and urban development played essential role in shaping and transforming land use land cover of this island. Although various development projects were undertaken to support tourism industry, not much changes of its land use land cover had occurred in the last 30 years. Table 3 shows land use/land cover changes from 1974 to 2005. Built-up area category increased quite significantly where this land use land cover activity covers only 133.4 ha in 1974, it increased to 1192.6 ha in 1985. By 1992, additional 93 ha of built-up area was recorded. However, between 1992 and 2005, it reached 3137.2 ha. Area undergoing significant changes mostly centered around Kuah area and near existing population centers such as in Padang Mat Sirat and Pantai Cenang. Figure 3 shows land use land cover of Langkawi Island from 1974 to 2005.

Apart from built-up area, other types of land use land cover categories did not change much in the last thirty years. As shown in Table 3, mixed agriculture area decreased from 57.5 ha in 1974 to approximately 34.8 ha in 2005. On the other hand, the area used for rubber had increased from 3681.1ha in 1974 and became 5685.5ha in 1985. This is probably due to rural development policy implemented where the government through the Rural Development Authority opened up forested land to give way to commercial agriculture such as rubber to be undertaken by the rural poor. After 1985, however, land use for rubber plantation decreased to make ways for other development. In 1985 rubber comprised of 5685.5 ha and decreased to 4327.9ha in 2005. The same situation could be seen for forest area where it decreased from 24,543.6 ha to 21,383.6ha between 1974 and 2005 respectively.

Arguably, not much land has been developed in the last 30 years to cater for the increase of its population and to support tourism activities. This is due to

Table 3: Land use land cover and its area from 1974 to 2005.

Category	1974 (hectares)	1985 (hectares)	1992 (hectares)	2005 (hectares)
Built-up area	133.38	1192.65	1285.62	3137.24
Mixed Agriculture	57.47	34.75	34.75	34.75
Rubber	3681.12	5685.49	4597.91	4327.91
Paddy	3576.49	2872.88	3902.21	3522.22
Forest	24543.57	22315.22	22322.48	21383.56
Water Body	644.27	623.22	632.22	529.28
Village	3672.88	3609.05	3593.05	3407.30
<b>Total</b>	<b>36309.17</b>	<b>36333.26</b>	<b>36368.25</b>	<b>36342.26</b>

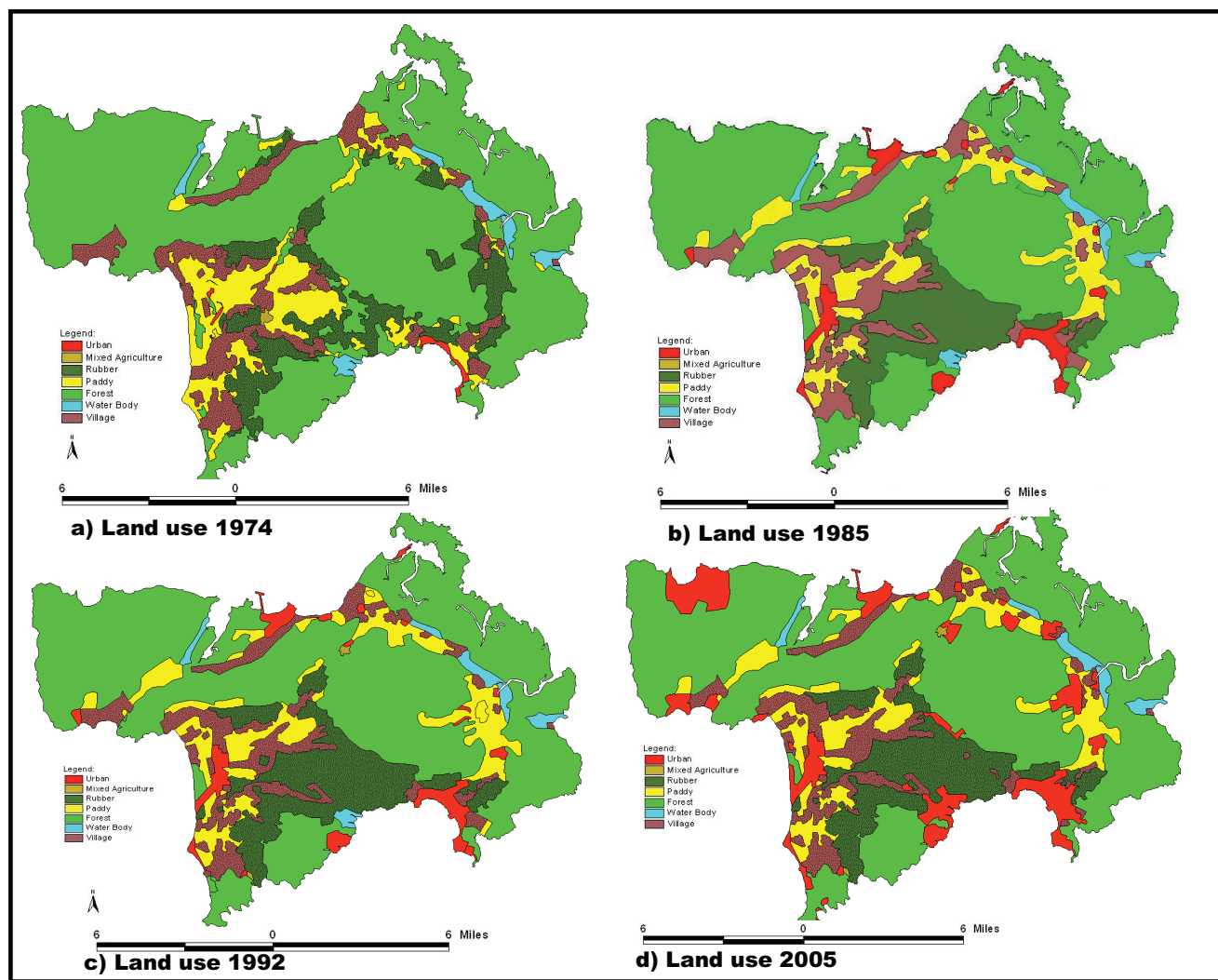


Figure 3: Land use distribution in Langkawi Island from 1974 and 2005.

urban development was undertaken in a control manner and directed toward specific zones. Urban built-up areas centered around Kuah area, which is an administrative, commercial and service centers for the island. In addition, development of tourism activity usually was undertaken sporadically in area with scenic beauty or other attraction.

Evaluation on annual urban expansion index, however, revealed more interesting results. This index shows the speed of urban expansion per unit area. This statistics showed that many parts of the island experienced high-speed of annual urban expansion (see scale in Table 1 above). Between 1974 and 1985, small area of the island experienced high-speed of urban expansion which included Kuah, Padang Mat Sirat and Teluk Ewa (Figure 4). This period (1974-1985) was the era of New Economic Policy where agriculture activity played major role in promoting economic activity of the nation. Land use/land cover transformation during that era was related to mainly on changing forest to agriculture area in order to generate the economy of the rural

poor. Urban expansion occurred mainly near existing population and administrative center.

Not much urban development occurred between 1985 and 1992. Although the government policy during this period geared toward urbanization and industrialization (Gomez and Jomo, 1997), not much land being developed in Langkawi Island. This is probably due to the location of the island that is quite far from major urban centers (such as Kuala Lumpur and Georgetown). However, post 1992 period, after Langkawi Island was being given a duty-free-status in 1987, urban expansion had occurred quite drastically in Kuah, Air Hangat and Pokok Asam areas. Other areas that experienced high-speed of urban expansion included Datai Bay, Pantai Kok, and Pantai Chenang. Areas underwent fast-speed urban expansion included Tanjung Malai, Kg. Telok and Kg Belanga Pechah (see Figure 4 below). Admittedly, land use land cover transformation that had occurred in these areas mainly to support tourism sector resulted from top-down land use allocation strategy.

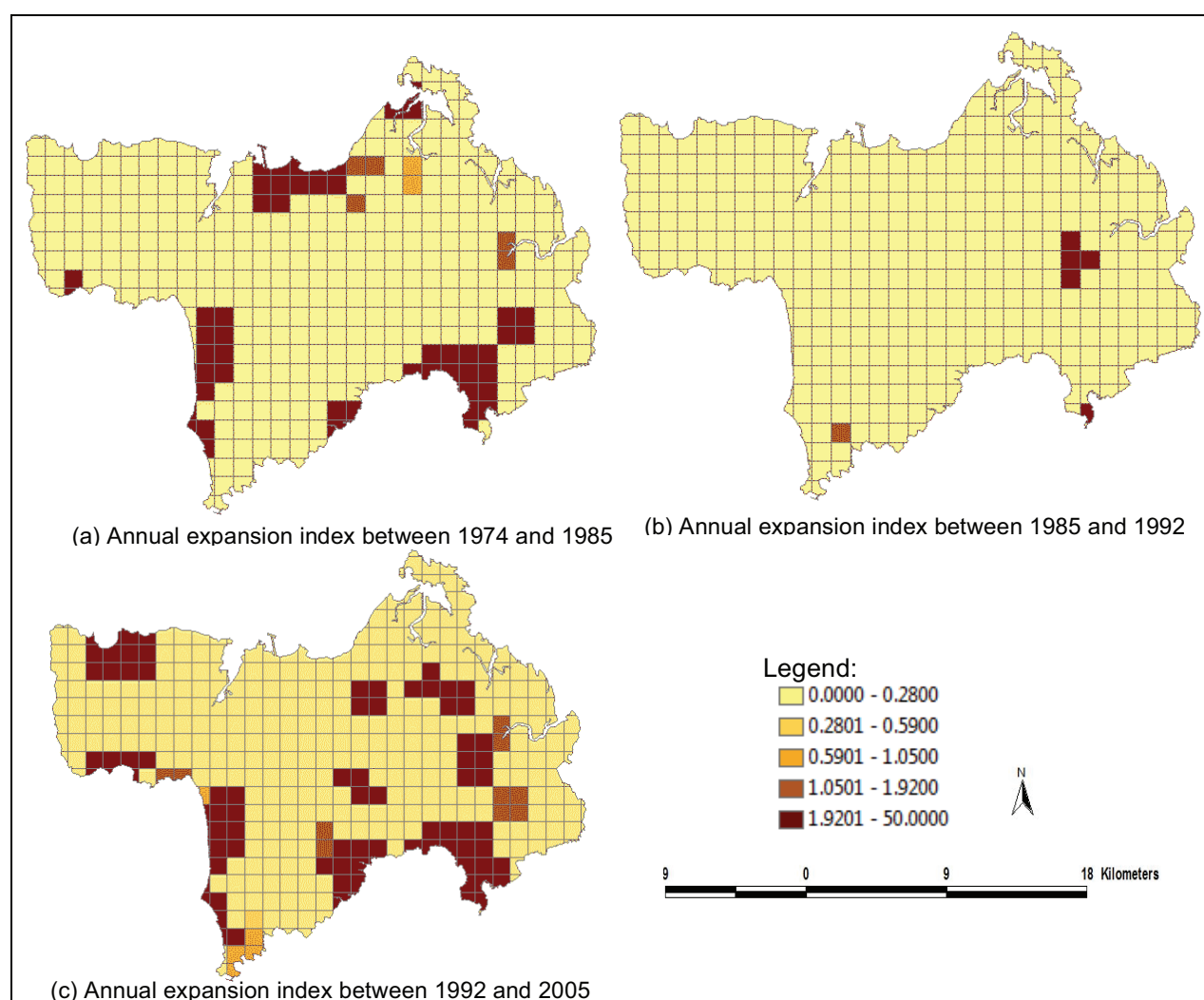


Figure 4: Annual expansion intensity index between 1974 and 2005

Assessment of land use land cover changes that has occurred in Langkawi Island during 1974 and 2005 period revealed that the speed of expansion was quite worrying. Although the government policy intended to direct urban built-up area to center near Kuah area, the development of hotels and other facilities to support tourism industry tends to be developed throughout the island resulting in patches of built-up area on the island. Annual urban expansion intensity index calculated at the size of 1km<sup>2</sup> suggested that high speed of urban development in many parts of the island including in the forested areas. Such development needs to be monitored and controlled in order to ensure the sustainability of the people and the tourism industry.

The study was undertaken at a regional scale where land use/land cover was divided into seven broad categories. Therefore, land use/land cover changes at this scale does could only show the statistics and area experiencing land use land cover transformation. The study at local scale should be undertaken in order to evaluate species diversity and changes of landscape

and its impact on biodiversity. Furthermore, the study also should be extended to include developing land use land cover model in order to monitor and predict future direction of land use land cover transformation of the island. Such an approach would allow planners and policy makers to evaluate and test the impact of proposed development plan on the sustainability of urban development.

## CONCLUSION

Langkawi Island had undergone significant land use land cover transformation in the last thirty years. It was undertaken in a controlled manner where urban development directed toward existing urban built-up areas. The evaluation on annual urban expansion index, however, revealed that many part of the islands experience high-speed of urban development between 1992 and 2005. It is, therefore, essential that urban planners and policy makers evaluate and monitor land use/land cover changes in order to ensure that this transition does not harm the society, economy and environment.



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